User Manual
RF Play/Record System

“Sample”

CAL-BAY SYSTEMS
Solutions for Test, Measurement & Automation

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Overview

The Cal-Bay RF Play/Record System (RFPR) is an instrumentation platform and software package designed to acquire, record, analyze and recreate (play) RF signals in the 9kHz to 2.7GHz frequency range. Unlike a traditional spectrum analyzer, the RFPR system has the ability to record a specified frequency band to hard disk continuously and capture transient RF events for subsequent offline analysis, troubleshooting and reproduction.

Scope of Document

This document describes the functionality of the RFPR system from an application software perspective. This document may be used as a reference manual for day-to-day operation of the system. Further information about the hardware design and construction may be found in a separate document, titled: “System Design, RF Play/Record System”.

Startup and Shutdown

Application Startup

The RFPR application software may be started in the same manner as any other Windows application. Simply double click the "RF Play-Record" icon on the desktop, as shown in Figure 1; the software will initialize all instrumentation to a default state and then display the front panel user interface.

If, for some reason, this shortcut icon is accidentally deleted or unavailable, a new Windows shortcut or Start Menu item may be created. This shortcut should point to the following file: `c:\program files\rfpr\RFPR.exe`

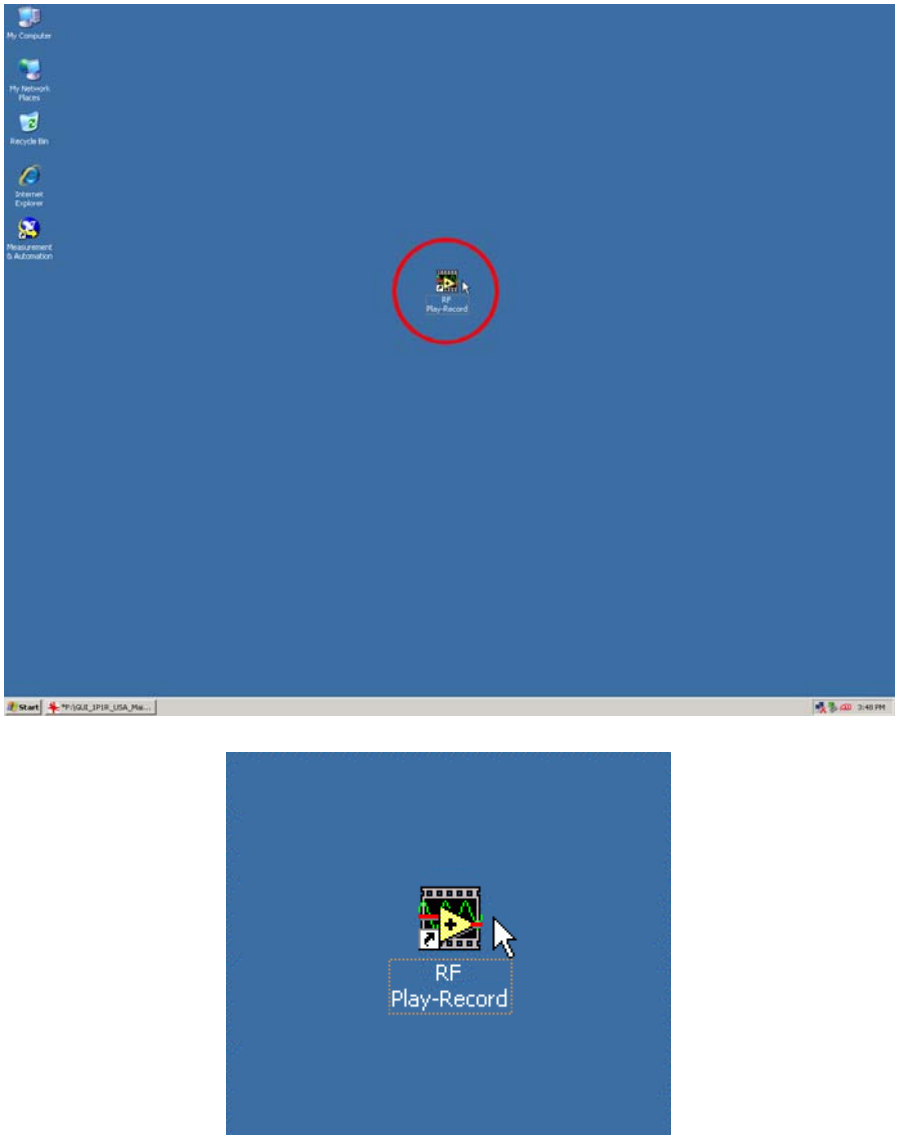


Figure 1 – Application Startup Icon

Application Shutdown

The RFPR application software may be shutdown in the same manner as a typical Windows application. Select the File / Exit menu option, as shown below in Figure 2.

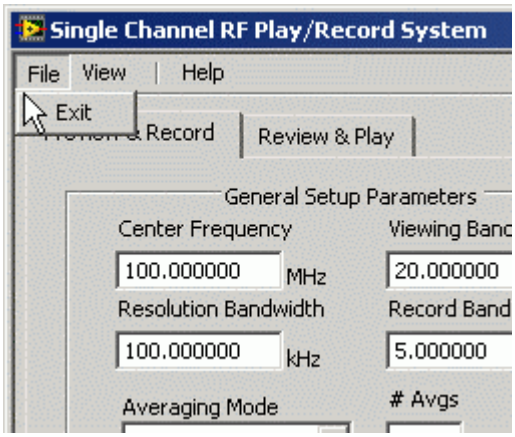


Figure 2 - Application Exit

Fundamental Concepts

Operation Modes

The RFPR software is designed to support four fundamental user activities, or "Operation Modes". These Operation Modes are:

Preview Operation Mode

Preview is the default Operation Mode on startup. This mode allows you to search for, identify and view incoming RF signals. The basic functionality is similar to a traditional spectrum analyzer.

Record Operation Mode

Once a signal of interest has been identified, and you wish to record this signal, depress the "Record…" button to transition the system into the Record Operation Mode. In this mode, the system records the selected RF signal to the hard disk array continuously and displays a pseudo real-time spectrum on the front panel (depending on available CPU resources and record bandwidth).

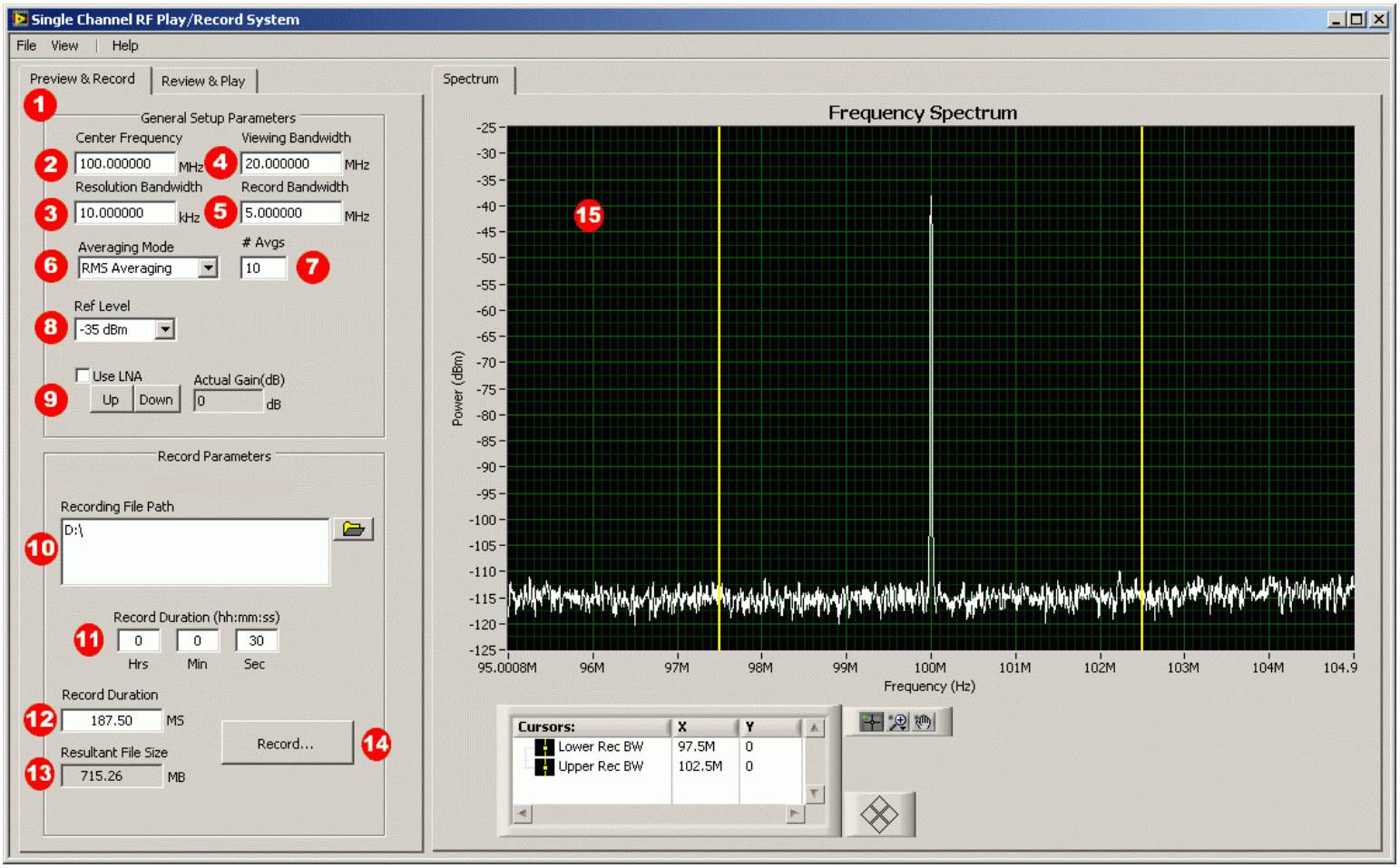
Review Operation Mode

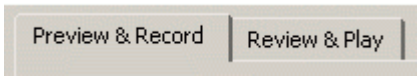
The Review Operation Mode allows you to view previously recorded signals. After selecting a recording file, you may view the spectrum of the recorded signal at any specified time within the recording or continuously scroll through the recording and view the spectrum of the signal as a function of time. (Note that the Review Operation mode does not control any instrumentation hardware, it simply recalls a recording from the disk array and displays the contents on the front panel).

Play Operation Mode

The Play Operation Mode allows you to reproduce a previously recorded RF signal. After selecting a recording file, and depressing the "Play to RF Out…" button, the recording will be streamed to the RF Output port of the system. The signal is reproduced at the original recording center frequency, bandwidth and power level.

Preview and Record Controls





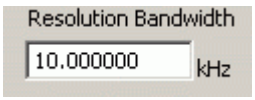
(1) Preview & Record (Tab Selection)

When selected, this tab configures the system to operate in Preview and Record Operation Modes. When this tab is initially selected, the system automatically enters Preview mode. Preview mode mimics the basic functionality of a traditional spectrum analyzer. This mode may be used to identify incoming RF signals, and configure the instrumentation for subsequent RF Recording operations.

The system automatically transitions Preview mode into Record mode after the Record button (described below) is depressed.

(2) Center Frequency

Sets the center frequency of the record/analysis instrumentation; this control affects *both* the immediate record preview display and also subsequent recording operations.



(3) Resolution Bandwidth

Sets the Resolution Bandwidth of the spectrum display. Applicable only in record preview mode; this control does not affect any aspect of the recording function.

(4) Viewing Bandwidth

Sets the span of the spectrum plot's horizontal axis. This control is analogous to the "span" setting in a traditional spectrum analyzer. This control *does not affect record operations*.

Adjustments to the viewing bandwidth will tradeoff screen update rate and resolution bandwidth (similar to trade-offs in a conventional spectrum analyzer).

(5) Record Bandwidth

Sets the bandwidth of the signal that will be recorded after the "Record…" button is pressed.

While the system is in Preview mode (i.e. not Recording), this control only adjusts the frequency span between the two yellow vertical lines on the spectral display, which indicate record bandwidth. This control has no other impact on the instrumentation or software as long as the system remains in Preview mode.

Once Recording begins, the value of this control will determine the IQ Rate of the resultant recording, and therefore the usable, flat signal bandwidth of the recording.

The usable, flat signal bandwidth is always 0.8 * IQ Rate. For example, a 5MHz Record Bandwidth setting will result in a recording file with an IQ Rate of 6.25Msamples/sec and a usable, flat signal bandwidth of 5MHz.

(6) Averaging Mode

Sets the type of averaging (if any) that will be applied to the signal spectrum during record preview mode only. This control does not affect any aspect of the recording function.

(7) # Avgs

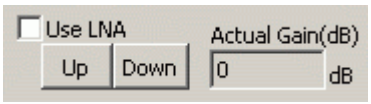
Sets the number of signal acquisitions that should be averaged together on screen, using an averaging method as specified by the "Averaging Mode" control. This control does not affect any aspect of the recording function.

(8) Ref Level

Controls input attenuation and/or gain of the Vector Signal Analyzer (VSA) front end. Applies during *both* record preview and subsequent record active operations.

Adjust this control to a level that is slightly higher than the expected RF input level. A setting that is too low may cause VSA overload. A setting that is too high will degrade sensitivity performance.

As a rule of thumb, set this control 5dB higher than the *total* power of the expected input signal. If the total input power is unknown, start at a high level and adjust downward until an appropriate tradeoff between noise floor and signal distortion/intermodulation is found.

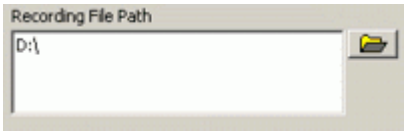


(9) Use LNA

Enables or Bypasses the system RF Preamplifier (aka Low Noise Amplifier or LNA). Up/Down buttons adjust the gain attenuation of the LNA in approximately 1dB steps. Actual Gain applied to the RF signal is calculated by the LNA hardware[1] and indicated on screen. These controls apply to both preview and recording functions.

The LNA may be used in weak signal situations (for example, off-air recordings from antennas). However, particular care must be taken to ensure that the LNA does not overload as a result of nearby strong signals. It is important to remember that the LNA does not have any frequency selectivity. For example, a very strong undesired signal that is 100MHz away from the current center frequency may still push the LNA into non-linear operation and affect the fidelity of the desired signal. Therefore, the LNA should be enabled only in very weak signal cases, when it is necessary to "pull a weak signal out of the noise", or in cases where the operator has high confidence that large undesired signals are not present.

For further discussion about how the LNA affects the signal power values displayed on screen, see the section of the user manual entitled: "Calibration Reference Plane".



(10) Recording File Path

Sets the destination *directory* of subsequent recordings. The small yellow folder icon in the upper right hand corner of this control may be used to open a standard Windows dialog box to select an existing directory as the destination (you may also use the Windows dialog box to create new directories using standard Windows dialog box conventions).

Note that new signal recordings will *always* use a filename that consists of the current date and time. Therefore, this control sets only the destination *directory*, not the destination *filename.*

(11) Record Duration (hh:mm:ss)

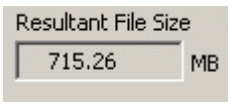
Sets the recording duration in hours, minutes, seconds units. Note that if your total recording duration is not know a priori, you may set this duration to a high value, and then Abort the recording early if necessary (even an aborted recording will remain valid and preserved on the disk array).

[1] The pre-amplifier hardware has an internal firmware look-up table, which contains calibration factors for all system center frequencies. As LNA gain is increased or decreased, the pre-amplifier considers the current system center frequency when reporting how much *actual gain* is currently applied to the signal.

(12) Record Duration (MS)

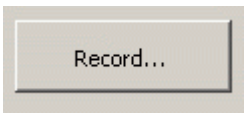
This control may also be used to specify the recording duration in MSample units, instead of hh:mm:ss time units. This may be useful in instances where you wish to create a recording with a specific file size, rather than time duration.

Inputs to this control will simultaneously update the Record Duration (hh:mm:ss) control.



(13) Resultant File Size

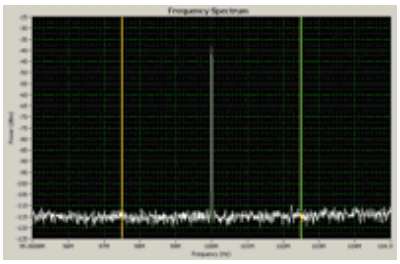
Indicates the expected file size of the configured recording in MByte units. This is a display only field, which cannot be updated by the user.



(14) Record Button

Initiates Record operations. Upon pressing this button, the system will transition from "Preview" mode to "Record" mode, and signal recording will commence.

Once recording begins, it is no longer possible to adjust parameters such as center frequency, record bandwidth, and ref level.



(15) Frequency Spectrum Plot

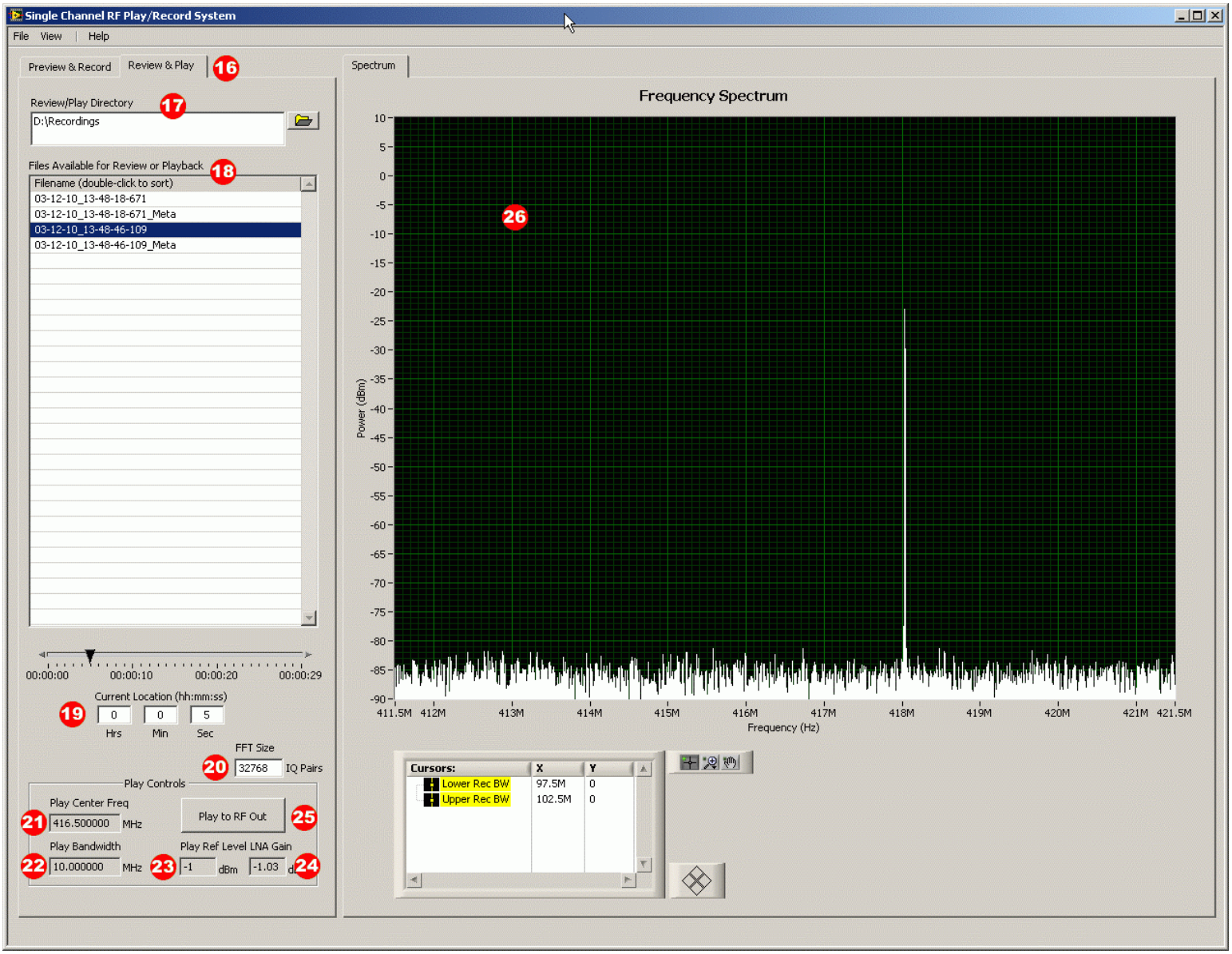
Displays a variety of frequency domain spectral data, depending on the system mode of operation. Vertical scale is always calibrated logarithmic power (dBm units) and horizontal scale is always frequency (Hz units).

The display normally auto-scales to fit the incoming signal. However, it is also possible to manually re-scale the display by clicking on any of the black numeric values and typing in a new value (on either the x or y scale). For example, to adjust the maximum power level displayed, simply click on the number at the top left corner of the plot display and replace the old value with the desired new value.

During Record Preview mode, two vertical yellow lines will be displayed. These lines indicate the record bandwidth (i.e. the portion of the spectrum that will actually be recorded).

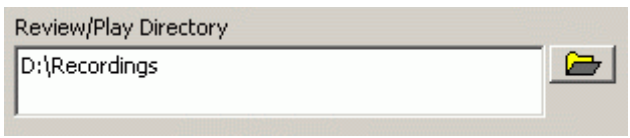
During Record Active mode, the vertical yellow lines disappear, the horizontal axis re-scales, and only the spectrum that is actually being recorded is displayed on the plot.

Review and Play Controls



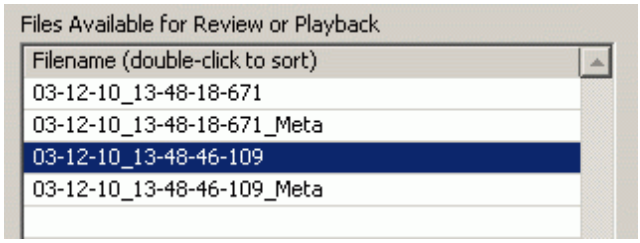
(16) Review & Play

Configures the system to operate in Review & Playback mode. This mode allows you to view the spectral characteristics of files previously recorded on-screen, and play (reproduce) these files out to the system's RF Output.



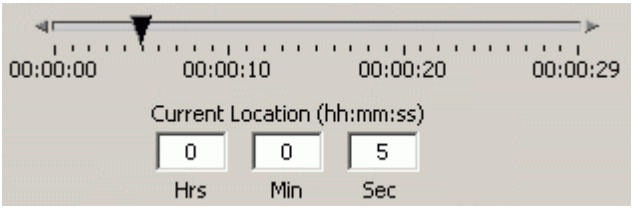
(17) Review/Play Directory

Specifies the directory (folder) to search for RF Recordings.



(18) Files Available for Review or Playback

A list of all files contained within the Review/Play Directory. Left click on any RF Recording filename in the list to immediately view the recording's spectral contents in the adjacent Frequency Spectrum Plot window. Note that a scrollbar along the right edge of this control allows you to scroll the list up and down to fully display all directory contents.

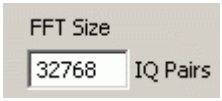


(19) Current Location (hh:mm:ss) and Horizontal Slider Bar

Controls the current viewing position within the selected RF Recording file. Enter a value (using hh:mm:ss time units) to view the spectral contents of the selected RF recording at a specified time offset from the recording start (the start time of the recording always equals 0 seconds).

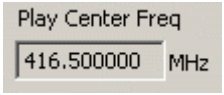
Alternatively, use the horizontal slider bar above the hh:mm:ss control to continuously scroll through the recording. (To scroll, left click on the black, downward pointing triangle and drag the mouse cursor left or right).

Note that the maximum (right edge) scale of the horizontal slider bar adjusts to equal the total length of the currently selected RF Recording.



(20) FFT Size

Sets how many IQ Pairs should be sampled when performing the FFT calculations for the Frequency Spectrum Plot. A higher value will result in improved spectral resolution, but longer processing time and a longer sampling window.



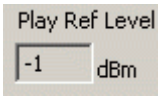
(21) Play Center Freq

Indicates the original Center Frequency of the currently selected RF Recording. When Playback is initiated, the recording will be reproduced at this frequency.

(22) Play Bandwidth

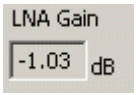
Indicates the original Bandwidth of the currently selected RF Recording. When Playback is initiated, the recording will be reproduced at this bandwidth (aka IQ Rate or Sample Rate).

Note that the displayed bandwidth is the usable, flat signal bandwidth, and equals 0.8 * IQ Rate. For example, if a 5MHz Play Bandwidth is indicated, the actual IQ Rate during playback will be 6.25Msamples/sec.



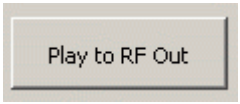
(23) Play Ref Level

Indicates the VSA Ref Level used while recording the currently selected RF Recording. When Playback is initiated, this value will be used to configure the playback instrumentation to recreate the RF signal level originally present at the Antenna Input connector.



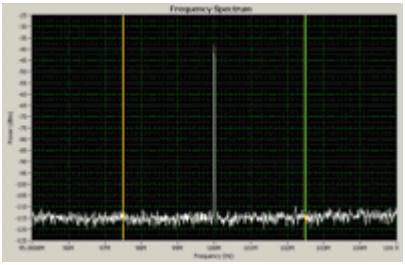
(24) LNA Gain

Indicates the LNA Gain used while recording the currently selected RF Recording. When Playback is initiated, this value will be combined with the previously described Ref Level to calculate and recreate the RF signal level originally present at the Antenna Input connector.



(25) Play to RF Out

Initiates Play Operations. The currently selected RF Recording is streamed to the play instrumentation in real-time, and the signal is reproduced at the system's RF Output connector. The signal's center frequency, bandwidth and RF power level will match the values set/calculated during the original RF Recording.



(26) Frequency Spectrum Plot

Displays a variety of frequency domain spectral data, depending on the system mode of operation. Vertical scale is always calibrated logarithmic power (dBm units) and horizontal scale is always frequency (Hz units).

The display normally auto-scales to fit the current signal. However, it is also possible to manually re-scale the display by clicking on any of the black numeric values and typing in a new value (on either the x or y scale). For example, to adjust the maximum power level displayed, simply click on the number at the top left corner of the plot display and replace the old value with the desired new value.

Calibration Reference Plane

The RFPR System employs several internal calibration factors to ensure that the power level of incoming RF signals is accurately represented during preview/record operations, and that the playback operations likewise reproduce RF signals at the expected levels.

The Calibration Reference Plane for the RFPR System is the Input/Output connector panel on the top of the instrumentation cart assembly.

A 0dBm signal presented at the "Antenna J1" connector should result in a nominal 0dBm on-screen signal level during preview mode. Similarly, a signal recorded at 0dBm should result in a 0dBm signal output level at the "RF Output J2" connector during playback mode.

In order to accomplish these objectives, the RFPR system software considers National Instruments hardware calibration factors, internal cabling losses, *and the current state of the Low Noise Amplifier (LNA).*

Essence and Metadata Files

When the RFPR System records an RF signal, two files are actually created on the system RAID: an *essence* file and a *metadata* file.

The essence filename is automatically generated from the control PC's date and time (at the recording start time). The metadata filename is identical to the essence filename, but adds the suffix: "_Meta" to the end. For example, a recording started at 1:30PM on Dec 31, 2009 would create two files as follows:

Essence Filename: `12-31-2009_13-30-00-000` (time units are: hh-mm-ss-msec)
Metadata Filename: `12-31-2009_13-30-00-000_Meta`

The essence file contains the RF signal data (or, more precisely, the raw IQ data of the downconverted RF signal).

The metadata file contains information that describes the contents of the essence file. The metadata file preserves critical information such as the center frequency and bandwidth during the recording. It also contains information such as calibration factors, gain values and error status.

This metadata information is ***critical*** to proper operation of the RFPR system. For example, without the metadata file, there would be no mathematical way to determine the original sample rate of the RF recording. Therefore, it is imperative to maintain the integrity of the metadata file and ensure that the essence file (raw RF recording) and metadata file are always archived together. Similarly, if the filename of the essence data is changed (using Windows Explorer or other external utilities), then the filename of the metadata file must be changed correspondingly (taking care to preserve the "_Meta" filename suffix).

Note that the format of the metadata file is a regular ASCII plain text file, with Tab delimited fields. Therefore, metadata files may be easily opened in any text editor, such as Windows Notepad. Advanced users may choose to alter some metadata parameters such as center frequency; however particular care should be taken to ensure that the correct numerical units are used and that all Tab delimiters between fields are maintained.

Large File Considerations

RF Recording essence files can become extremely large, depending on the signal bandwidth and duration of each recording. File sizes can easily exceed 4GB, which means that reading/writing/copying these files requires a file system format that can handle an address range larger than 2^32 bytes.

The NTFS file system (native to newer versions of MS Windows) is rapidly becoming ubiquitous and can easily accommodate very large file sizes. Modern Linux file systems are similarly able to accommodate very large file sizes. Note that the most universal file system format, FAT32, **cannot** handle files > 4GB. Unfortunately, FAT32 is still often the default used by PC manufacturers to format USB memory sticks, external USB hard drives, and some internal PC hard drives.

Therefore, when copying files from the RFPR System and archiving on external devices, be sure to consider the file system format used on the destination device. You may find it necessary to reformat the destination disk to use NTFS or some other modern file system format.